

We claim:

1. A method of processing a workpiece with a plasma in a vacuum plasma processing chamber comprising the step of exciting the plasma with electric energy at several frequencies such that the excitation of the plasma by the several frequencies simultaneously causes several different phenomena to occur in the plasma.
2. The method of claim 1 wherein the number of frequencies is three.
3. The method of claim 2 further comprising selecting the frequencies to affect the density of the plasma, the energy of ions in the plasma, and the chemistry of the plasma, and applying the selected frequencies to the plasma.
4. The method of claim 3 wherein the several frequencies simultaneously excite the plasma.
5. The method of claim 3 wherein the first frequency is in the range of 100 kHz to 10 MHz, the second frequency is in the range of 10 MHz to 150 MHz, and the third frequency is in the range of 27 MHz to 300 MHz.
6. The method of claim 1 wherein various combinations of the several frequencies affect (a) the density of the plasma (b) the energy of ions, and (c) the chemistry of the plasma.
7. The method of claim 1 wherein the several frequencies simultaneously excite the plasma.
8. The method of claim 1 wherein a first of the frequencies is in the range of 100 kHz to 10 MHz, a second of the frequencies is in the range of 10 MHz to 150 MHz, and a third of the frequencies is in the range of 27 MHz to 300 MHz.

9. The method of claim 1 further including confining the plasma to a region removed from sidewalls of the chamber.

10. The method of claim 9 further including controlling the pressure of the plasma in the region.

11. The method of claim 1 further including varying the spacing between a pair of electrodes in the chamber between which the plasma is excited.

12. The method of claim 1 further including varying the power of at least one of the several frequencies.

13. The method of claim 1 further including exciting the plasma with a pair of opposed electrodes, coupling power at at least one of the several frequencies to at least one of the electrodes, and selectively coupling power at one of the several frequencies from one of the electrodes to RF ground.

14. The method of claim 1 further including exciting the plasma with a pair of opposed electrodes, and controlling the temperatures of the opposed electrodes while the workpiece is being processed.

15. Apparatus for processing a workpiece with a plasma comprising a vacuum chamber for processing the workpiece with the plasma, and means for exciting the plasma with electric energy at several frequencies such that the excitation of the plasma by the several frequencies simultaneously causes several different phenomena to occur in the plasma.

16. A vacuum plasma processor comprising a vacuum chamber including an electrode, the chamber being associated with a reactance, the electrode and reactance being arranged for coupling plasma excitation fields to gas in the chamber, the chamber being arranged for

carrying the workpiece, and a plasma excitation source arrangement for enabling the electrode and reactance to couple the electric energy at several frequencies to the plasma.

17. The vacuum plasma processor of claim 16 wherein the plasma excitation source arrangement is arranged for causing the several frequencies to be simultaneously applied to the plasma.

18. The vacuum plasma processor of claim 16 wherein the electrode for carrying the workpiece includes a first electrode in the chamber and the reactance includes a second electrode in the chamber.

19. The vacuum plasma processor of claim 18 wherein the plasma excitation source arrangement is arranged for applying a plurality of the frequencies to the first electrode and at least one of the frequencies to the second electrode.

20. The vacuum plasma processor of claim 16 wherein the plasma excitation source arrangement is arranged for applying several of the frequencies to the electrode.

21. The vacuum plasma processor of claim 18 wherein the first and second electrodes and the source arrangement are arranged for causing the second electrode to be at a reference potential and for simultaneously causing the source arrangement to apply the several frequencies to the first electrode.

22. The vacuum plasma processor of claim 16 wherein the plasma excitation source arrangement includes at least one variable frequency RF source.

23. The vacuum plasma processor of claim 16 wherein the plasma excitation source arrangement includes circuitry for (a) providing an impedance match between sources of the frequencies and the plasma and (b) decoupling the frequencies associated with the different sources from each of the other sources.

24. The vacuum plasma processor of claim 16 wherein the excitation source arrangement is arranged and the frequencies have values for causing several different phenomena to occur simultaneously in the plasma.

25. A vacuum plasma processor for a workpiece comprising a vacuum chamber including first and second electrodes for supplying plasma excitation fields to a region of the chamber adapted to be responsive to gas adapted to be converted into a plasma for processing the workpiece, the chamber being arranged for carrying the workpiece, a plasma excitation source arrangement for deriving electric energy at several frequencies, the plasma excitation source arrangement including circuitry for selectively enabling coupling of the several frequencies to at least one of the first and second electrodes for enabling plasma exciting electric fields at the several frequencies to be coupled to the plasma.

26. The processor of claim 25 wherein the circuitry is arranged for coupling a plurality of the frequencies to the first electrode and for coupling at least one of the frequencies to the second electrode.

27. The processor of claim 25 wherein the circuitry is arranged for (a) providing an impedance match between sources of the frequencies and the plasma and (b) decoupling the frequencies associated with the different sources from each of the other sources.

28. The processor of claim 25 wherein the plasma excitation source arrangement includes several different frequency sources.

29. The processor of claim 28 wherein at least one of the sources has a variable frequency.

30. The processor of claim 28 wherein at least one of the sources has a fixed frequency.

31. The processor of claim 28 wherein various combinations of the several frequencies affect (a) the density of the plasma (b) the energy of ions in the plasma, and (c) the chemistry of the plasma.

32. The processor of claim 28 wherein at least one of the sources has a variable output power.

33. The processor of claim 25 wherein the circuitry and the chamber are arranged for preventing substantial current to flow at at least one of the plurality of frequencies to the second electrode.

34. The processor of claim 33 wherein the circuitry and the chamber arrangement for preventing substantial current to flow at at least one of the plurality of frequencies to the second electrode includes (a) a surface in the chamber at a reference potential for causing current to flow at at least one of the plurality of frequencies from the first electrode to the surface and (b) a filter arrangement of the circuitry, the filter arrangement being connected to the second electrode for preventing the substantial flow of current at at least one of the plurality of frequencies between the second electrode and the reference potential.

35. The processor of claim 25 wherein the circuitry is arranged for connecting the second electrode to a reference potential and for supplying the several frequencies to the first electrode.

36. The processor of claim 25 wherein the circuitry is arranged for supplying the same frequency to the first and second electrodes.

37. The processor of claim 25 wherein the plasma source arrangement circuitry is arranged for simultaneously coupling the several frequencies with the electrodes.

38. The processor of claim 25 wherein the circuitry includes a controller for selectively connecting the second electrode to a reference potential during a first workpiece processing time period and for selectively supplying the same frequency to the first and second electrodes during a second work time piece period.

39. The processor of claim 37 wherein the controller is arranged for selectively connecting the first electrode to be responsive to each of the several frequencies during the first time period interval.

40. The vacuum plasma processor of claim 25 wherein the plasma excitation source arrangement is arranged for applying several of the frequencies to the first electrode.

41. The vacuum plasma processor of claim 25 wherein the first and second electrodes and the source arrangement are arranged for causing the second electrode to be at a reference potential and for simultaneously causing the source arrangement to apply the several frequencies to the first electrode.

42. A vacuum plasma processor for processing a workpiece comprising a vacuum chamber including an electrode arrangement for supplying plasma excitation fields to a region of the chamber adapted to be responsive to gas adapted to be converted into a plasma for processing the workpiece, the electrode arrangement including first and second electrodes respectively on opposite first and second sides of the region and a third electrode on said first side of the region, the third electrode being peripheral to and electrically insulated from the first electrode, a plasma excitation source arrangement for deriving electric energy at plural frequencies, the plasma excitation source arrangement being arranged for selectively coupling energy at the plural frequencies to the first, second and third electrodes for causing current at at least one of the plural frequencies to flow in the third electrode without current at all of the frequencies flowing through the third electrode.

43. The processor of claim 42 wherein the electrode arrangement includes a fourth

electrode on said second side of the region, the fourth electrode being peripheral to and electrically insulated from the second electrode, the plasma excitation source arrangement being arranged for selectively coupling energy to the fourth electrode for causing current at at least one of plural frequencies to flow in the fourth electrode without current at all the frequencies flowing through the fourth electrode.

44. The processor of claim 43 wherein the plasma excitation source arrangement is arranged for applying energy at at least one of the frequencies to the third electrode.

45. The processor of claim 43 wherein the plasma excitation source arrangement is arranged for applying energy at at least one of the frequencies to the fourth electrode.

46. The processor of claim 43 wherein the plasma excitation source arrangement is arranged for applying energy at at least one of the frequencies to the third and fourth electrodes.

47. The processor of claim 43 wherein the plasma excitation source arrangement includes a filter arrangement for enabling current at at least one of the frequencies to flow between the third electrode and a reference potential while preventing at at least one of the frequencies from flowing between the third electrode and the reference potential.

48. The processor of claim 43 wherein the plasma excitation source arrangement includes a filter arrangement for enabling current at at least one of the frequencies to flow between the fourth electrode and a reference potential while preventing at at least one of the frequencies from flowing between the fourth electrode and the reference potential.

49. The processor of claim 48 wherein the plasma excitation source arrangement includes a filter arrangement for enabling current at at least one of the frequencies to flow between the third electrode and a reference potential while preventing at at least one of the frequencies from flowing between the third electrode and the reference potential.

50. The processor of claim 42 wherein the plasma excitation source arrangement is arranged for applying energy at at least one of the frequencies to the third electrode.

51. The processor of claim 42 wherein the plasma excitation source arrangement includes a filter arrangement for enabling current at at least one of the frequencies to flow between the third electrode and a reference potential while preventing at at least one of the frequencies from flowing between the third electrode and the reference potential.

52. A method of processing a workpiece in a vacuum plasma processor including a vacuum chamber including an electrode arrangement for supplying plasma excitation fields to a region of the chamber responsive to gas that is converted into a plasma that processes the workpiece, the electrode arrangement including first and second electrodes respectively on opposite first and second sides of the region and a third electrode on said first side of the region, the third electrode being peripheral to and electrically insulated from the first electrode, the method comprising coupling energy at plural frequencies to the first, second and third electrodes so that current at at least one of the plural frequencies flows in the third electrode without current at all of the frequencies flowing through the third electrode.

53. The method of claim 52 wherein the electrode arrangement includes a fourth electrode on said second side of the region, the fourth electrode being peripheral to and electrically insulated from the second electrode, the method further comprising selectively coupling energy to the fourth electrode so current at at least one of the plural frequencies flows in the fourth electrode without current at all the frequencies flowing through the fourth electrode.

54. The method of claim 53 wherein the energy is coupled to the third electrode by connecting to the third electrode a power source arrangement having at least one of the frequencies.



55. The method of claim 54 wherein the energy is coupled to the fourth electrode by connecting to the fourth electrode a power source arrangement having at least one of the frequencies.

56. The method of claim 55 wherein the energy is coupled to the third electrode by connecting to the third electrode a power source arrangement having at least one of the frequencies.

57. The method of claim 53 wherein the energy is coupled to the third electrode by connecting between the third electrode and a reference potential a filter arrangement that passes at least one of the frequencies and blocks at least one of the frequencies.

58. The method of claim 53 wherein the energy is coupled to the fourth electrode by connecting between the fourth electrode and a reference potential a filter arrangement that passes at least one of the frequencies and blocks at least one of the frequencies.

59. The method of claim 58 wherein the energy is coupled to the third electrode by connecting between the third electrode and a reference potential a filter arrangement that passes at least one of the frequencies and blocks at least one of the frequencies.

60. The method of claim 52 wherein the energy is coupled to the third electrode by connecting to the third electrode a power source arrangement having at least one of the frequencies.

61. The method of claim 52 wherein the energy is coupled to the third electrode by connecting between the third electrode and a reference potential a filter arrangement that passes at least one of the frequencies and blocks at least one of the frequencies.